Index

AISC Specification, 24, 25, 28, 45, 243, 264, 306, 464, 472, 473, 475, 476
AISC/ASD Specification, 46, 80–5
AISC/LRFD Specification, 28, 30, 84–6
AISC/PD Specification, 80–4
Allowable stress, 466–7
Allowable Stress Design (ASD), 39
American Surety Building, 9, 11
Analysis
  methods, 24
  rules, USA, 469–75
ASD Specification, 465, 468, 469, 471, 472, 473
  construction types, 465–7
ATC, 468

Backing plates, 447
Base shear coefficient curves, 168
Bauschinger effect, 284
Beam-to-column connections
  combinations of connector types, 474–5
  design rules, 365–7
Beam-to-column moment connections, 394–407
Beam-to-end-plate welds, 156
  design, 133–40
Bearing
  connections, 468–9
  stiffeners, 473
  stresses, 45–6
Bending deflection, 76
Bending deformation, 112
Block shear, 472
Bolted connections, 21–2, 44–5
  backing plates, 447–8
  bolt design, 140–1
  bolt tightening, 456–8
  categories of, 430–2
  combined tension and shear, 437–8
  design
    bolts, of, 441–5
    capacity, 431, 434
    rules, 359–62, 377–80, 430–51
Bolted connections—*contd.*
  effective net area, 475
  end-plate design, 445–6
  extended end-plates, 395–9
    including bolt design, 152–6
  fabrication, 456–9
  flange-welded web-bolted, 57, 101–8
  flush end-plates including bolt design, 144–52
  friction capacity, 435
  fully-bolted, 66–74, 108–11
  high-strength bolts in slip-resistant connections, 435–8
  high-strength structural, 468–9
  moment capacity calculation, 447
  moment capacity of unstiffened, 438–47
  non-preloaded bolts, 456
  preloaded bolts, 456
  preloading force, 435
  rotational capacity, 429–30
  slip factor, 436
  slip-resistant, 457
  strength of individual fasteners, 432–5
  strengthening of unstiffened, 447–51
  traditional stiffeners between column flanges, 447
  ultimate shear force in web panel, 446
  ultimate tensile force
    unstiffened flange, on, 440
    unstiffened web, on, 446
  web plate, 448–51
Box-shape columns, 277
BS5950, 376, 380, 391, 402, 407
Buckling deformations, 206
Buckling load, 206

Cage construction, 14–15
Canadian Code, 231
Castigliano's theorems, 24
Circular hollow section columns, 277
Clapeyron's theorem, 24
Codes, 24

Column
  Deflection Curve (CDC) approach, 220
  flange
    adequacy of, 399–401
    bending, 158–9
  Research Council, 207
  splices, 367
  stiffeners, 144, 473–4
  strength curve, 228
  web
    buckling, 85
    compression zone, in, 401–2
    shear in, 402
    tension zone, in, 401
    yielding, 84–5
Columns
  box-shape, 277
  circular hollow section, 277
  connection behaviour and modeling, 212–6
  cross-H, 277
  design
    based on limit states principles, 204–6
    considering end restraint, 216–7
    method, 230–6
    problem, 203–4
    recommendation, 234–6
  effects of connections on, 201–39
  end-restrained, 210–17
  H-shape, 275
  initial out-of-straightness, 208–9
  initially crooked, 216
  methods of analyses, 219–21
  multiple column curve concept, 209–10
  pin-ended, 206–10
  results of analyses, 221–30
  rotational restraints from connections and beams, 217–9
Composite beam-to-column connections, 274
Compression zone, 81–3
Connecting plate, 166
Connections
  flexibility, 251
  standardisation, 391–4
  use of term, 27, 166
Connectors, 18–22
Construction types
  ASD Specification, 465–7
  LRFD Specification, 467
Construction types, 2, 3
  see also Type; Type 1
Contact surfaces, 459
CRC basic column curve, 208
Critical load, 206
Cross-H columns, 277

Deflection
  due to joint rotation, 112–4
  due to out-of-plane deformation of column web, 114–5
Deformation
  capacity, 311–2
  effects, 31–2
Design
  methods, 24
  fully-rigid, 376
  semi-rigid, 376
    simple, 376
  requirements, 27–8
  rules, 2
    Europe, 415–62
    Japan, 357–74
    United Kingdom, 375–413
    USA, 463–76
Detailing rules, 475–6
Dimensional accuracy, 386–91
Displacement method, 248
Doubler plate, 166
Drift comparison, 298
Ductility, 128–9, 308–13
  factors, 33
  ratios, 33
  requirements, 32–3

Eccentrically braced frames (EBFs)
  characteristics of, 325–9
  connection details, 349–52
  design
    concepts, 343–8
    philosophy, 344–8
    procedures, 344–8
  distinguishing characteristic of, 321
  energy dissipation mechanisms, 328–9
  experimental results, 330–41
  forces in links, 327–8
  K-braced, 345
  link details, 348–9
  link length, 341–2
  non-seismic applications, 352
  preliminary design considerations, 343–344
  seismic-resistant, 321–354
  shear link with bolted web connection, 335
  stiffener spacing and link rotation, 342–3

Eccentrically braced frames—*contd.*
stiffness and strength, 325–6
tests
composite links, on, 338–41
links with equal end moments, on, 331–6
links with unequal end moments, on, 336–8
three-story subassemblages, on, 330–1
typical bracing arrangements, 322
US–Japan Cooperative Program, 341
wind bracing applications, 352
Eccentricity, 471–2
Edge cuts, 460
Effective length factor, 211–2, 226–30
Elastic behavior, 273–4, 286–92
Elastic buckling, 206
Elastic design, 21, 394, 417
Elastic frame analysis, 24
Elastic joint stiffness prediction, 111–21
Elastic loading, 206
Elastic–plastic analysis of moment frames, 292
End-plate connections, 394
see also Moment end-plate connections
End-plate design, 397–9
Equivalent imperfection, 209
Eurocodes, 415–6
basic design philosophy, 416–30
Europe, design rules, 415–62
Extended end-plate connections, 395–402
Exterior diaphragms, 314
Exterior subassemblage, 310

Fabrication, 455–61
bolted connections, 456–9
welded connections, 461
Failure
modes, 63
zone, 55
Fasteners, 18–22, 44–5
Finite element analysis, 122–6
Flange bending, 142–3
Flange continuity plate, 166
Flatiron Building, 11
Flexible connections, 391–2
Flexibly connected frames
automatic design, 263–6
behavior under working loads, 252–5
effects of connection non-linearity, 256–9
experimental verification, 262–3
internal moments in, 252–4
linear analysis, 247–52
Flexibly connected frames—*contd.*
non-linear analysis, 255–63
strength of, 259–62
sway of, 254–5
Flush end-plate connections, 402–5
Force distribution, 469–70
Fourth and Blanchard Building, 165
Fracture of moment plate, 175
Frame
drift index versus frame slenderness, 254
stability, 32
subassemblages
deformation capacity, 312
yield deformation, 312
Frames
current practice, 242
effects
connection flexibility, of, 241–2
connections, of, 241–67
joint-panel shear deformation, of, 269–320
historical review, 242
outline of approach, 242–3
see also Flexibly connected frames
Friction
connections, 469
surfaces, 459
Full-strength connections, 418
Fully-restrained construction, 467

Generalised slope-deflection method, 286–8
G-factors, 212
Gillender Building, 17
Gravity loading forces, 271

Holes, 44–5, 380–2, 458–9
Home Insurance Building, 3, 4, 8
Horizontal loading forces, 271
H-shape columns, 275
Hysteretic curves, 284,285

Inelastic behavior, 278–84, 292
Interior subassemblage, 310
Iron Bridge, 21

Japan, design rules, 357–74
Joint assemblage under repeated and reversed loading, 284
Joint-panels
behavior of, 271–84

Joint-panels—*contd.*
design formulae, 274–8
elastic behavior, 273–4, 286–92
inelastic behavior, 278–84, 292
influence of shear deformation on frame behavior, 286–92
maximum strength, 278–84
shear deformation of, 269–320
yield strength, 273–4
yielding of, 311
Joint rotation, deflection due to, 112–4
Joints
classification, 417–8
use of term, 27, 166

Knee braces, 16

Lack of fit, 386–91
Lattice girders, 16
Limit state, 465
design basis, 467
principles of, 204–6
Load and Resistance Factor Design (LRFD), 39, 164, 195, 465
Load-deflection
approach, 204
behavior, analytical predictions of, 111–26
curves, 53, 60, 65, 69, 71, 76, 101, 222
hysteretic loops, 172
problem, 208–9
Load deformation
curve, 437
hysteresis, 182
Local buckling, 313–5
Local deformation, 313–5
Longitudinal stresses, 128
LRFD Specification, 468–72, 475
construction types, 467

Matrix stiffness method, 288–92, 315
examples, 292–304
Maximum strength, 278–84
design rules, 368–74
Menier Building, 17, 19
Metropolitan Life Tower, 11
Minimum connection capacity, 468
Moment connections, design rules, 365–7
Moment–curvature relationship, 61
Moment
distribution, 24

Moment—*contd.*
end-plate connections, 133–62
beam-to-end-plate welds, 133–40, 156
column side design, 141–4
end-plate design, 136–9
extended end-plates including bolt design, 152–6
fabrication/erection considerations, 136
flush end-plates including bolt design, 144–52
principal advantages and disadvantages, 136
recommendations for future research, 159–60
recommended design procedures, 144–59
review of literature, 136–44
ratio charts, 156–7
Moment-resisting connections
beam-to-column flanges, 187–9
beam-to-column webs, 190–1
calculations, 183–7
code developments, 195
cyclic behavior
beam-to-column connections, of, 170–5
panel zones, of, 170, 175–82
design philosophy, 163–6
ductile frames, 164
experiments on, 170–87, 193–5
flange and web column splices, 191–3
flange connections, 183–4
free-body diagram, 166
full-size cantilever specimen, 169
interior column moment and shear diagrams, 177
interior column subassemblages, 176
internal stiffener plate, 189
joint design problem, 166–8
panel zone
deformation, 178
design, 185–7
tests, 181
recent developments, 193–5
required rotations at joints, 167
single-degree-of-freedom systems, 168
test procedures for joint evaluation, 169–70
typical connections, 187–93
typical cyclic loading sequence, 169
unbalanced moment vs. panel zone distortion, 179
web connections, 184–5

Moment-resisting frames (MRFs). *See* Moment-resisting connections
Moment–rotation
  behavior, 41, 246
  curves, 28, 42, 214–5, 217, 219, 226, 244, 419, 424, 426
Monotonic curves, 284, 285

NEHRP, 323, 330, 333, 335, 344, 347–9
Non-linear finite element analysis, 125–6
Non-linear moment–rotation behavior, 243–4
NONSAP, 125
Nuts, 456

Out-of-plane deformation of column web, deformation due to, 114–5

Panel zone, 34, 166
  cyclic behavior, 175–82
  deformation, 78–80, 178
  tests, 181
  see also Moment-resisting connections
Panel zone shear stress versus shear strain, 281
Park Row Building, 8, 9, 10, 16
Partial restraint, 471
Partially restrained construction, 467, 471
Partial-strength connections, design philosophy, 418–30
Performance rules, 465–9
Perry–Robertson formula, 209
Plastic
  analysis
    high shear force, with, 76–80
    simple, 74–6, 111
  buckling, 206–8
  design, 25, 418, 419
  hinges, 55
Portal frame connections, 405–7
Portals, 16
Predictability, 33–4
Prying action, 441, 442, 472
  design rules, 382–6
Punched holes, design rules, 380–2

Railroad bridges, 20
Rand McNally Building, 6
Reduced modulus load, 206
Relative stiffness, 211
Reliance Building, 7, 8, 9
Rigid frame construction. *See* Type 1
Riveted joints, 20, 21
Rotational capacity requirement, 420–4, 426–30
Rotational restraint, 468

SEAOC, 193, 195, 330, 333, 335, 344, 347–50
Seismic loading, design against failure due to, 468
Seismic moment connections. *See* Moment-resisting connections
Semi-rigid construction. *See* Type 3
Shear–drift curves, 305, 307–9
Shear
  deformation, 112
  force, 80
  joint-panels of. *See* Joint-panels
  stiffening of column web, 84
  stress–strain behavior, 77
  tab, 166
  yielding, 85–6
Simple-frame construction. *See* Type 2
Singer Building, 11
Skeleton construction, 14–15
Slenderness, 205
Slenderness ratio, 204, 206
Slip-critical connections, 469
Slip-resistant lap joint, 73
Slope-deflection method, 24, 292, 315
Specifications, 24
Squash load, 204
Standardisation of connections, 391–4
Static flange moment connections, 39–88
  behavior and test highlights
    flange-welded web-bolted connections, 57–66
    fully-bolted connections, 66–74
    fully-welded connections, 47–57
  current provisions, 80–6
  design principles and criteria, 41–6
  theoretical analyses, 74–80
Static web moment connections, 89–131
  background, 92
  flange-welded web-bolted connections, 101–8
  full-scale test program, 97–8
  fully-bolted connections, 108–11
  fully-welded connection, 98–101
  modeling, 115–21
  pilot test program, 92–7
  previous research, 92

Steel
  beam-to-column building connections
    as structural elements, 1
    classification, 28–30
    effect on entire framework, 2, 22
    elements of connection behaviour, 27–30
  frame building construction, 3–12
  Structures Research Committee, 22–4
Stiffener
  use of term, 166
  rules, 43
Stiffness
  characteristics, 22
  distribution, 425
  effects, 31–2
  equation, 291, 304
  requirements, 420–6
Straightness, initial lack of, 208
Strain
  hardening, 308
  reversal, 206
Strength criteria, 30–1
Strength–stiffness relations, 244–5
Stress distributions, 127
Structural Stability Research Council, 207, 216
Surface protection, 460
Sway rods, 16
Synthetic curves, 285

Tangent-modulus load, 206
Tension
  connections, 469
  flange fracture, 85
  zone, 83–4
Test specimens, 23
Times Building, 11
Top-and-seat-angle connections, 246
Truss members, 367
T-stubs, 441, 442
Type 1 (rigid-frame) construction, 28, 29, 31, 33, 39, 41, 242, 264, 266, 393, 417, 466, 470
Type 2 (simple frame) construction, 25, 28, 29, 31, 242, 252, 253, 264, 266, 417, 466, 467, 471, 472
Type 3 (semi-rigid frame) construction, 28, 29, 32, 242, 252, 254, 407–9, 417, 466, 467, 471
Type FR (fully restrained) construction, 29, 39, 41
Type PR (partially restrained) construction, 29

Ultimate shear strength, 308–13
Ultimate strength, 30–1
  design criteria, 367–74
Uniform Building Code, 168, 195, 464, 468
United Kingdom, design rules, 375–413
USA, design rules, 463–75

Venetian Building, 18, 19
Virtual work methods, 24
Von Mises yield criterion, 273

Washers, 456
Web
  buckling, 142, 157
Web connections. *See* Static web moment connections
  plates, 166, 448–51
  yielding, 141–2, 156–7
Weld fracture, 57
Welded connections, 21, 44, 451–5
  beam-to-end-plate welds, 156
  capacity of, 453–5
  design of weld between beam flange and column, 453–4
  design rules, 362–5
  extended end-plate, 399
  fabrication, 461
  flange-welded web-bolted, 57, 101–8
  fully-welded, 47–57, 98–101
  rotational capacity, 427
  strength of individual fillet welds, 451–2
  ultimate compressive (web crippling) or tensile force on unstiffened web, 453
  ultimate shear force in web panel, 455
  ultimate tensile force on unstiffened flange, 453
Welding, 21
Wind bracing, 12–18
Woolworth Building, 3, 11–13
World War II, 23, 25

Yield
  line analysis, 121–2
  strength, 273–4